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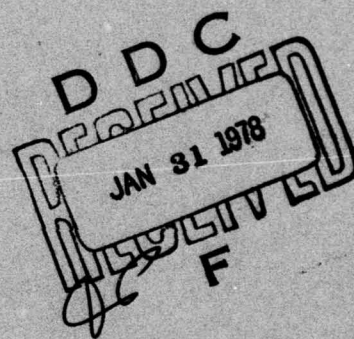MICROCOPY RESOLUTION TEST CHART

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RADC-TR-77-373
Final Technical Report
November 1977

# THE CARTOGRAPHIC SYSTEM

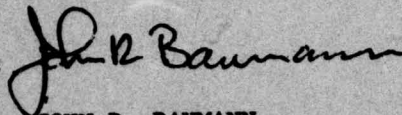John Decker
Aldo DiPasqua
Allen Lazzara

Synectics Corporation

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JAN 31 1978

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York   13441

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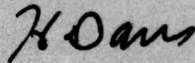
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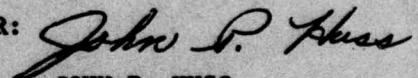
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This report describes a cartographic digitizing system developed for the Instituto Geografico Militare Italiano.  The cartographic system was designed to provide a means to rapidly acquire digital files from analog cartographic data using manual and computer interactive techniques.  This objective is effected by the use of tutorial displays which guide the operator in the digitizing session and indicate his rate of accomplishment.  The system provides for verification plotting on a high speed drum plotter and for final product plotting on the IGMI contraves plotter.

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## ACKNOWLEDGEMENT

## EVALUATION

For several years RADC has participated in a Cooperative Research and Development program between the United States Department of Defense and the Italian Ministry of Defense.

The objective of the program is to develop photogrammetric and cartographic equipment on a joint R&D basis with each country contributing where technologically superior. The program is divided into three phases:

Phase I provided a fully automated Off-line Orthoprinter which produces high resolution orthographically restituted imagery (free of camera geometry and attutide distortions and of relief parallax) from high altitude reconnaissance camera data.

Phase II of the program addressed the development of a 3-stage photogrammetric instrument (PC-1) for the USAF, optimized for exploiting orthophoto/setereomate reconstructed deployable, photogrammetric data base material. Digitized terrain intelligence data and target positions can be quickly produced in support of Weapon delivery and strike operations in the field. The Catographic System, which is the subject of this report, was developed under Phase II and provides the IGMI in Florence, Italy (National Military Mapping Installation) a semi-automated graphic digitizing system designed to produce digital data base files to support automated production of revised and different scaled military maps for use by NATO.

Phase III will address the development of an improved Off-line Large Format Orthoprinter designed to produce highly simplified deployable photogrammetric Target System (PTS). In addition, a Cartographic Digitizing/Processing system based on and compatible with the IGMI Cartographic System, will be developed by RADC for the IAF to generate digital terrain and feature files in support of Radar Landmass Simulators and Radar Prediction Systems in NATO.

JOHN R. BAUMANN
Project Engineer

# SECTION 1

## INTRODUCTION

### 1.1 General

This report is the final technical report for the Cooperative Cartographic System. The information herein is in fulfillment of the obligations set forth in Contract No. F30602-75-C-0329. Companion documents which provide very detailed technical information are:

- o Cartographic System Program Documentation
- o Cartographic System Users Manual
- o Test Plans and Procedures for the Cartographic System

### 1.2 Background

For several years, RADC has participated in a Cooperative Research and Development program between the United States Department of Defense and the Italian Ministry of Defense. Recently, this cooperative agreement was extended to in include the additional task of "Automation in Cartography". Under this task, RADC, with participation from the Italian Geographic Military Institute specified techniques to enhance the speed and efficiency of the digitization process. The implementation contract was awarded to Synectics Corporation on 30 June 1975.

The purpose of this effort was to provide a baseline experimental configuration which would serve as a common test bed for subsequent joint development of advanced digitization concepts and techniques. This implied that the delivered system would be highly reliable, easily maintained and totally compatible with the research facilities used at both IGMI and RADC. Synectics was also aware of the fact that the Cartographic System would be used as a production tool to aid in IGMI's mapping programs, necessitating further system reliability and usability than that normally found in R&D systems.

## 1.3 Cartographic System General Function

The Cartographic System (CS) was designed to provide for a means of rapid acquisition of analog cartographic data using manual and computer-interactive techniques.  This objective is effected by generation of tutorial displays which guide the operator in the digitizing session and indicate his rate of accomplishment.

In addition to a digitizing package, the operator is supplied with a verification plotting capability which allows for the rapid plot of digitized features at any interim stage of the digitizing process on a high-speed Calcomp plotter.

Final product plotting at IGMI is performed on a Contraves Coragraph precision plotter, which requires paper tape-coded information as input.  This process thus generated a requirement for a program that converted CS-acquired digital data to Contraves-compatible code and produced an output paper tape for Contraves processing.

## 1.4 System Implementation Results

The following is extracted from the Synectics Trip Report based on the installation, demonstration, and training efforts conducted at the IGMI facility in Florence, Italy from 22 November - 3 December 1976.

### 22 November

- o Successful system power-up, using specified Italian power source.

- o Data General Nova 830 software fully operational, as is Cartographic System Software

- o Datagrid digitizer operational after resealing IC boards in controller and Nova computer interface

- o Calcomp 936 plotter operational after two attempts to re-seat IC components

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## 23 November

o Demonstration of improved Contraves conversion with Calcomp
  proof plotting capability

o Second version of Contraves conversion process, using angle/
  distance thinning produced acceptable graphics on Contraves
  Plotter.  Many parity errors were generated using the Data
  General standard high-speed punch unit.

o Patches were made to theContraves conversion program to allow
  for symbol definition at every discrete point feature

## 24 November

o Staff level presentation and demonstration of Cartographic
  System

o Modifications were made to the Contraves software to output
  data by selective feature category.

## 25 November

o Final hardware adjustments involving the CPU were made.  Rust
  appeared in the Calcomp pen turret barrels and was cleaned out.

o Final system diagnostics were run for a prolonged period to
  check all components

## 26 November

o No errors resulted from diagnostic run the previous day

o Software course is commenced; the Data General Real Time
  Desk Operating System, from basic concepts through RDOS
  directory structure, will be covered

o J. Baumann (RADC) is assisting in training the CS operators
  while the Synectics staff is presenting the course material
  and hardware maintenance procedures.

## 29 November

o Course outline has been completed and Synectics software
code discussion has begun.

o Procedure for disk file update and recovery from a "hard"
system crash is covered.

## 30 November

o The Data General representative, from Milan, Italy, performed
hardware and software diagnostics to accept the system for
maintenance.  In doing so, the entire disk system was wiped
out, giving a "pseudo crash" condition.  Recovery was success-
fully demonstrated by re-booting the bottom disk and loading
it with programs stored on a top, backup disk.

## 1 December

o A review of the bulk of the Cartographic System software
took place.

o The use of diagnostic programs for the Bendix Datagrid Digitizer
and Calcomp 936 plotter was demonstrated.

o A typical program development session, including program entry,
compilation, loading, and execution, was demonstrated.

o Additional training of hardware maintenance personnel was given.

## 2 December

o The review of CS and Contraves software was continued.

o The Calcomp proof plotting module was corrected to permit
plotting of discrete points during a plotting overlay pass

o A short power fluctuation occurred which brought down the
system.  However, the system was brought up quickly and
successfully by basic system restart procedures.

<u>3 December</u>

o Final wrapup of training session

o Extensive use of the system was demonstrated by IGMI personnel
  in an unsupervised environment.

o By this time, it was evident that IGMI understood the system
  well enough to successfully operate, maintain and provide
  second-order training, when necessary.

As the above report illustrates, the final product developed was in con-
cert with the goals stressed in the Cooperative Program objective.

## SECTION 2
## GENERAL TECHNICAL APPROACH

### 2.1 System Overview

#### 2.1.1 Hardware Components

The hardware configuration of the Cartographic System consists of:

o 32K Data General Nova 830 Jumbo CPU

o ASR 33 Teletype

o 7 Track Tape Transport

o 5 Million Word Dual Disk Unit

o Hi-Speed Paper Tape Reader/Punch Unit

o Tektronix 4014-1 Video Display Terminal

o Bendix Datagrid Back-lighted Digitizing Table

#### 2.1.2 Software Components

Cartographic System software was written to be executed under the Data General Real Time Disk Operating System. CS software consists of three sections:

o CS Digitizing Software

o Calcomp Proof Plotting Software

o CS to Contraves Format Conversion and Paper Tape Producing Software

The majority of the computer programs are written in Data General Fortran IV with the remainder of the software written in Data General Extended Assembler Language.

Fortran IV was chosen as the main program language because of the following factors:

(1) It is universally known, which allows future software development compatibility with present programs and facilitates software understanding by the end customer.

CALCOMP 936
DRUM PLOTTER

TELETYPE

NOVA 830

LIGHT TABLE
DIGITIZER

TEKTRONIX 4014-1
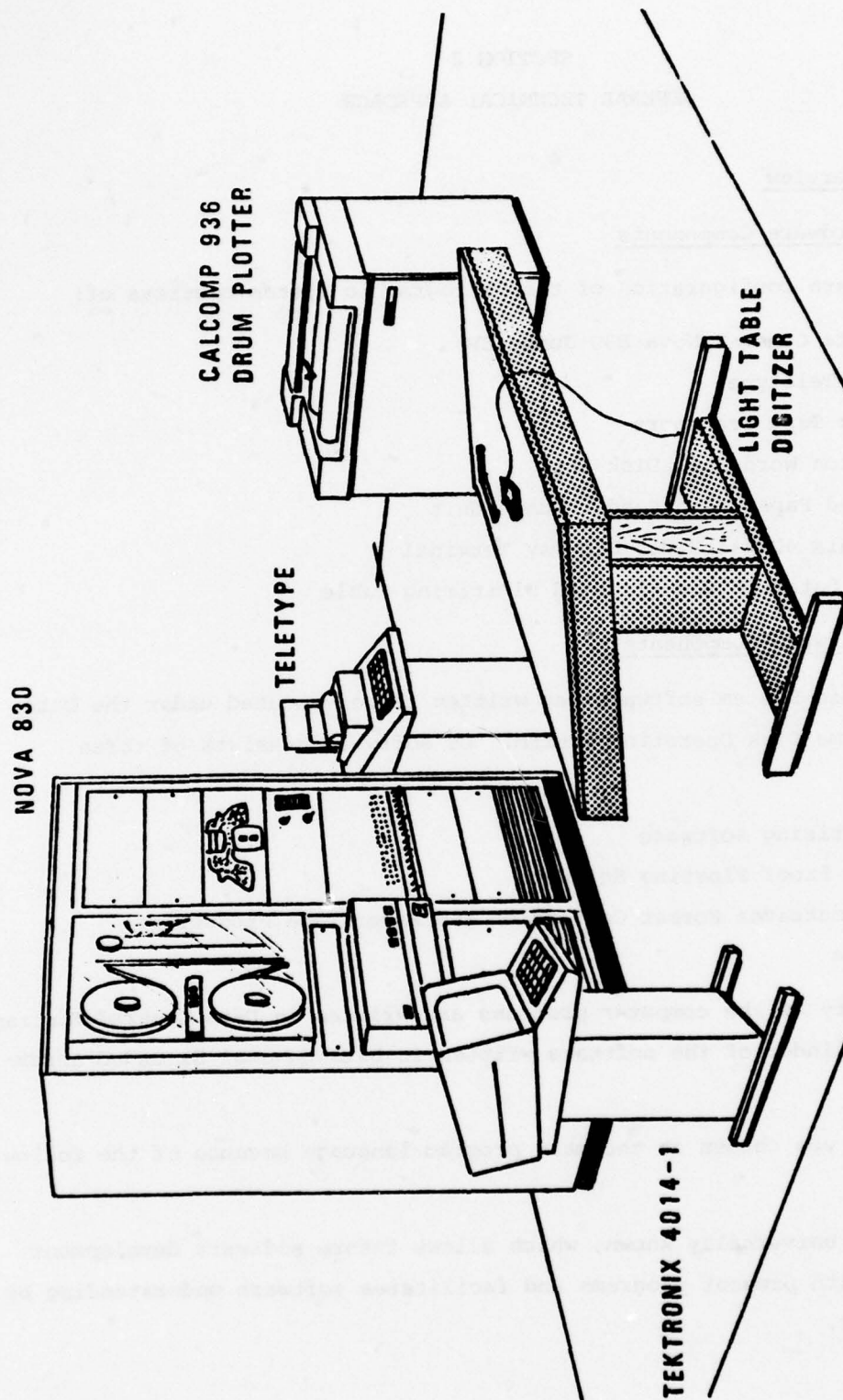
COOPERATIVE CARTOGRAPHIC SYSTEM

Figure 1-1

(2)  It was well suited to the specific requirements of the CS design such as display generation, operator interaction, and general purpose I/O.

(3)  Core restrictions were not a factor, since each mode of operation under the CS digitizing software could overlay sections of core when active and be overwritten in core when another mode was invoked.  There was no need to contain all the software in core simultaneously.

Assembler Language was used to perform functions in which timing is a critical factor.  It is also used to communicate with special peripherals such as the digitizing unit.

Refer to Section 3 'Software Functional Overview' for a more detailed software description).

## 2.2  Job Session Concept

Each CS process is organized to run as a job session.  A job consists of all operations persuant to a specific subset of cartographic data and can be either operator or graphic oriented.  It is merely a means of segregating and identifying processed data.

Each job run on the CS is recorded as three disk files, each unique to the job name.  These files are used for operating program control and data storage/ retrieval.  This arrangement facilitates interim wrap-up job re-entry procedures since the current status of each job can be restored to the CS by simply read- ing the job's disk files.  The three job files created by the CS digitizing software are the Header file, Parameter file, and Data file, and are named HFjobname, PFjobname, and DFjobname, respectively.

### 2.2.1  Header File

The Header file consists of headers or feature string labels chosen by the digitizing operator from a disk library of headers found in the Tavole dei Segni Convenzionali, the IGMI-published standard for all cartographic feature labels.  In addition, each time a new permanent header is created during the digitizing process, it is appended to the Header file.  Each header entry is stored as a string of ASCII characters.  The following is an example of a header entry:

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where the seven digit code represents the header's feature code and Contraves
plotter pen weight code, and the rest of the field is the Italian textual header
description. The Header file is page-organized into 16 headers each and is ex-
pandable to a maximum of 1006 headers.

### 2.2.2 Parameter File

The Parameter file is used to record the status of a job to insure proper
wrap-up/re-entry. Information contained in this file includes entries such as
job name, disk and tape recording/output resolutions, location of next available
data block for feature storage, graphic placement registration/correlation
values, and elapsed times in each of the modes of operation utilized in the
digitizing process.

### 2.2.3 Data File

The Data File is used to store the digitized feature strings along with
their corresponding identifying header labels. Consequently, the Data File
consists of two different block types: Header and Data block.

### Header Block

The Header Block records a feature header and contains information de-
fining characteristics of the following feature, such as the high/low and
first/last X,Y coordinate feature values, and whether the feature consists of
discrete points or is lineal.

### Data Block

The Data Block is used to store the digitized feature X,Y string. In order
to efficiently utilize disk space, several data word types are used, such as
short/long vectors, absolute point pair/trio, recording resolution set/change,
and end of data word. (See 'Cartographic System Program Documentation' manual
for more details).

Both the Calcomp plotting and Contraves Conversion modules are organized to accept the job-related information created by the Digitizing software to perform their specific tasks.

## 2.3 Polling Techniques

The CS digitizing software is controlled directly by operator responses to the interactive scenarios presented by the system on the CRT display terminal. Responses originate from cursor pushbutton and movement actions and use of the display keyboard. Each response generates different results when performed at different stages in the digitizing process resulting in a more dynamic use of available operator cues.

Two approaches are usually considered when designing a system configuration involving computer general data processing and specialized device control. One approach is to implement "live" peripherals which send interrupts to the processor when they require control have data ready to transmit. This type of processing includes detecting interrupt messages, locating their source, and performing the necessary control processes to satisfy the demand of processor resources. As the Nova 830 does not contain vectored interrupt processing, time must be spent in locating the interrupt requestor through the use of a daisy-chain process which inspects each possible interruptor source within the system for the demand. Since this process seemed unnecessary in the single-user environment of the CS, a second approach using polling logic was implemented. Basically, the polling process involves the use of the available time-driven algorithms to check for peripheral activity. Each device is considered wholly controlled by the central processor and sends or receives data during the polling interval. The processor thus queries devices directly, which eliminates the need for the device identification process which takes place in an interrupt driven system. The polling approach as implemented on the Nova 830 involves use of the computer Real Time Clock. The clock was specified at system generation, to generate a pulse every millisecond. The polling interval used to control peripherals is set at two clock 'ticks', or 2 milliseconds. The following information is thus checked during the polling interval:

o Digitizing cursor incremental movements in X/Y direction
   (since last interval)

o Digitizing table status; i.e. the cursor pushbutton logic -
   (Red, Yellow, White, Blue, Green buttons pushed, or Overflow/
   Lockout)

o Keyboard responses

The polling interval is also used to allow adjustment of raw digitizer coordinates to "corrected" points, i.e. points within the frame of reference defined by a chart's original position on the digitizing table with respect to the table origin. These corrections are found from correlation equations derived from original to new chart position assuming that the chart had undergone several digitizing sessions and, in the interim, was take off the table and subsequently remounted.

Timing statistics collected by using a "500 time" counter to record elapsed seconds for each mode of operation in the digitizing process.

Implementing polling procedures to read data and control the Datagrid Digitizer necessitated hardware modification, which consisted of disabling the interrupt logic circuitry. A benefit gained by disabling table interrupts was that when the digitizing software was not executing, inadvertant pushbutton actions would not stop normal data processing procedures, a situation apparent before interrups had been removed.

The polling approach proved to be the easiest to implement and afforded the most effective use of computer resources in the single tasking environment.

Polling was not used in the Calcomp Plotting software mainly because the bulk of the software was purchased with the plotter, and was written using an interrupt appraoch.

# SECTION 3

## SOFTWARE FUNCTIONAL OVERVIEW

### 3.0 Software Functional Overview

#### General

CS digitizing software is used to acquire digital files of graphic sources in an interactive environment.

Each digitizing session is designed to create 'job' files which contain the necessary data relevant to recreate an analog reproduction image of the source graphic.

Within the CS digitizing session, the operator has the capability to select definitions or headers for each of the features which will be digitized. Once these headers are selected, the operator may digitize graphic features using any of three forms of digitizing available:

(1) Continuous tracing, which records feature data for each movement of the digitizing cursor over the graphic.

(2) Trace-Point tracing, which records XY positions. This method is used for straight-line segment digitizing.

(3) Discrete point digitizing.

In addition to the above capabilities, the CS provides the following options.

o A review capability to examine all features digitized within an area.

o Various editing capabilities such as interior feature segment editing, feature truncation, selective deletion, and feature appending.

o Registration and registration check options for performing future digitizing on the same graphic if it had been removed and remounted on the digitizing table.

3-1

o A conversion process from CS formatted disk data to RADC
MMS-32 data which outputs this data on magnetic tape.

o Creates proof plots on the Calcomp 936 plotter of the CS
digitized job files.

o Converts the feature data from the CS data base into the
Contraves CORA1 paper tape format to drive the Contraves
plotter.

## 3.1  CS Digitizing Software

This section will describe the functional software required to create a
digital file from a graphic source.

### 3.1.1  Executive Module

The Executive module is the overall job controller of the Cartographic
System.  In response to the users requests from the digitizer status and key-
board character codes, it manages the loading and unloading of all other oper-
ational mode overlays during a job session.

### 3.1.2  Initialization Mode

The Initialization Mode is the first mode called by the Digitizing Execu-
tive Module during a job session.  Its primary function is to request the oper-
ator to enter a job name, and to determine whether the job's files currently
exist on disk or not.  If the job is being reopened, its related parameters,
working header set, and data files are opened and the choice of retaining,
adding to, or replacing, the job's working header set is requested of the
operator.

If the job's files are not currently on disk; i.e., a new job name has
been entered, the initialization mode requests and accepts values for the de-
sired disk recording resolution, new job files, parameter, working header set,
and data.

### 3.1.3  Header Selection Mode

The Header Selection Mode is entered to create a working header set disk
file for a new job, or to add or replace an existing job's working header set.
The operator is requested to choose any of the available header categories
listed on the display screen.

Once a category is selected, a disk file containing the entire library of
headers is scanned for headers matching the selected category, and these headers
are displayed as a page or group of 16 headers.  The operator then selects which
of the 16 are to be put in the job's working header set by use of the Tektronix
thumbwheel-controlled cross-hair cursor, or can advance to the next page of
headers as desired.  If any relief feature headers are chosen, the operator
is requested to enter a signed elevation base value and contour interval after
header selection has been completed.

### 3.1.4  Registration Mode

Registration Mode is used to obtain a reference system for the graphic.
It is also used to calculate new equations which aid in correlating the chart
to its original position if it had been previously removed and then remounted
on the digitizing table.

If a new job is being defined, original permanent points of reference
will be required and stored.

### 3.1.5  Disk Capacity Calculation

This routine computes the number of unused 256 word blocks remaining on
the disk via the map directory.  The resulting number of blocks left may gen-
erate a warning message to the operator, or automatically shut down the digi-
tizing session.

### 3.1.6  Header Mode

Header mode provides for the selection and/or establishment of headers
(identification information) for lineal and discrete points.  It also provides
for the initiation of output processing options and parameters/condition changes.
As it is the central mode of the Digitizing System, it is entered after comple-
tion of any of the other mode processes; e.g. REGISTRATION, TRACE, EDIT, REVIEW,
etc.

3-3

The main Header mode display consists of instructions, at the top of display, a "page" of headers from the working header set disk file, and an elevation value.

Pages consist of groups of headers from the working header set, up to 16 headers per page.

### 3.1.7  Trace Mode

Trace mode is used to record and display feature coordinate data strings. Trace mode accepts and X,Y coordinate pair derived from the table and rounds each coordinate to thenearest multiple of the input recording resolution.

As the feature is being digitized, Trace mode determines cumulative feature bounding quadrangle coordinates, start/end coordinates, and calls a subroutine to plot a coarse-resolution facsimile of the feature track on the display screen.

### 3.1.8  Point Mode

Point mode is used to record and display discrete point feature X/Y locations. Point mode entry is indicated by a display consisting of instructions followed by the current header chosen in header mode, and a square representing the digitizing surface. A point that is recorded from any part of the digitizing surface will be displayed within the square.

### 3.1.9  Review Mode

The purpose of Review mode is to allow for examination of features, both lineal and discrete, within a job's disk data file. Features can be selectively reviewed by feature category, if desired. The Review mode will display features in a rectangular window area, with the current digitizer cursor position as the center of the area. Features whose table position is correlatible to within the display window bounds are displayed on the screen, in whole or in part, and in the order in which they were digitized.

### 3.1.10  Edit Mode

Edit mode allows examination of the current or most recent feature at various display scales, and provides for 'backup' type deletion of partial or total data strings.

When accessed, and after every Edit command, Edit performs three operations: a plot of the current feature (centered on its last point) on the display, a search for a point on the feature nearest to the present cursor position, and a plot of the cursor location on the display.

### 3.1.11 Registration Check Mode

Registration Check Mode is used when a job has been reopened to verify the positional accuracy of the analog source on the digitizing table. This mode provides the continuity required when the digitizing process in interrupted or when chart updates, revisions, etc. are necessary.

The user has the option to accept the registration or lift up the cursor causing loss of registration. Upon loss of registration, the graphic is re-registered.

### 3.1.12 Segment Edit Mode

Segment Edit Mode is a multiple purpose editing program designed to perform the following functions on any randomly selected feature:

(a) Segment replacement of the beginning, end, or interior to the feature

(b) Header replacement of the feature

(c) Deletion of the feature

This mode is entered after Trace mode. A feature string is drawn to the target feature desired, i.e., the feature which requires a changed header, deletion, or segment edit. The new feature string just drawn loses its relevance as a feature when entry is made to Segment Edit mode, and becomes a tag or pointer to the target feature, or a potential string addition.

In the first case, if used as a pointer, for locating a feature for deletion or header change, once the specified change has been made, the feature tag is deleted. If used as a segment for edit, it becomes merged with the original target feature. The segment and target feature are deleted and the newly created feature is appended to the data file.

### 3.1.13  Output Mode

The purpose of the Output Mode is to generate a standard MMS-32 format magnetic tape from the internal disk storage forms.

### 3.1.14  Session Close

The Session Close routines are used to close all open CS files and list job statistics.

## 3.2  Calcomp Proof Plotting Software

The Calcomp Output Processing Software is designed to read CS digitized job files and create proof plots on the Calcomp 936 plotter.

The software has the capability to generate multicolor overlays or simultaneous multicolor plots by assigning color pen codes to feature categories. In addition, selective plotting by feature category can be accomplished, such as, for example, a proof plot of all contours on a graphic.

The main purpose of generating proof plots is to have at hand immediate results of a digitizing session, so that the resultant plot can be verified with respect to the original graphic and errors can be annotated and later corrected by the digitizing software.

## 3.3  CS To Contraves Interface Software

The capability to convert CS acquired feature data to Contraves CORA 1 (8 channel, 6-bit code) paper tape is provided.

CS digital data is processed one feature at a time and is sent to a process buffer. When this buffer is full, it is output to paper tape. The feature processing begins by extracting the IGMI header codes and tool number from the feature header block. This information is converted to Contraves code and moved to the output buffer along with a Contraves header record (HDR), plot pen tool number record (TLN), and the plotter operator instruction record (OPE). Each feature X,Y selected through various thinning processes is first converted and then moved to the output buffer. Different Contraves record types are generated depending upon whether source data features are discrete points or lineal.

The CS operator is also given the option to obtain a readable dump of the Contraves tape being generated. A listing of this dump would be used as a desk check or verification aid during the Contraves plotting process.

## SECTION 4
## CONCLUSIONS AND RECOMMENDATIONS

### 4.1  General

This final section of the technical report addresses each of the general processing functions.  Conclusions and recommendations are delineated for each task from the standpoint of analysis and experience with the subject system.

### 4.2  CS Digitizing Process

The Digitizing process software is especially well suited to the single user system.  It is possible to extend this concept to a background-foreground environment, where, for example, digitizing is taking place in the foreground and Contraves conversion operates in the background.  However, if this type of operation is planned in the future, the following steps must be considered:

#### (1)  Additional Core Memory

The Nova 830 with 32K of memory uses approximately 14K for system overhead.  Using completely segregated background/foreground facilities requires additional core for shared system programs and the Memory Management and Protection unit.  In consideration of the sizes of the software modules, an additional 16K of memory, or 48K total, should be the minimum storage possible for background/foreground processing.

#### (2)  Tasking Environment

A tasking environment is one in which a number of discrete activities compete for system resources in an asynchronous manner.  Taking a background/ foreground or multi-user approach to the CS would require a complete delineation of all activities currently being performed by software to determine their interaction and effect on each other.  An example of this is the effect of performing disk I/O while digitizing a feature; i.e., recording cursor motion, vectorizing the incremental movements, checking table status, and tracing the track on the display screen.  Each activity must be assigned a level of priority with respect to other activities to determine the most effective use of system resources.

Another recommendation to be considered is the addition of a hardware floating point processor module. Various processes in the digitizing software perform extensive amounts of interpolation for purposes such as finding the closest point to a segment in Segment Edit mode, and resolution change/format conversion in Output mode (MMS processing). A floating point processing unit can provide an order of magnitude reduction in time for these processes.

## 4.3 Calcomp Proof Plotting Process

The Calcomp 936 drum plotter was a major source of problems throughout the entire effort. By the end of the project, the bulk of the hardware components had been either repaired or replaced. When the plotter was operational, fast, reliable plots could be obtained by using Synectics-modified Calcomp plotting routines.

Recommendations include the following:

(1) Use of a high speed flat-bed plotter. The inconvenience of placing a sheet of plotting paper on the flat bed is more than offset by the inconveniences of tearing the plot off the roll, re-adjusting the paper back on the roll, and having a small field of view available within the immediate locality of the pen turret.

(2) Generation of a symbol program to provide titles, dates, and other job-pertinent information in addition to elementary graphic symbology.

## 4.4 Contraves Conversion Process

The end products of Synectics efforts are a proof plot, and more importantly, a paper tape, which is used as input to a high precision finishing plotter. Three recommendations are in order:

(1) Purchase of a special, heavy duty reader-punch. The Data General reader/punch unit is not an effective bulk storage media device, as it was designed primarily to read and punch out programs and not extensive data files such as those required for proof plotting. In some instances, it was found that one job required more than an entire box of fan fold tape to be output. There are currently off-the-shelf units which can easily handle the capacities required at a much faster output rate with a fraction of the parity errors resulting from the present unit.

4-2

(2) Addition of a bulk-storage device on the Contraves Coragraph Plotter.
A peripheral, such as a magnetic tape or disk storage could save hours of pain-
staking paper tape loading, storing and correction procedures which are necess-
arey to insure a good plot. In addition to time saved on the Contraves end of
processing, the Nova 830 processing cycle time would be greatly reduced, since
the Contraves output data could be transfered to a much faster unit, for example,
magnetic tape, which is also inherently more reliable than paper tape.

(3) Purchase of a new finishing plotter. If this recommendation is
chosen, consideration should be given to the situation illustrated in Recommen-
dation (2). There are several plotters on the market today which offer mass
storage features. Another feature to examine is the plotter controller oper-
ating system. It should provide a means of error detection and easy operator
recovery procedures. This was not apparent in the Contraves plotter controlling
system; however, allowances must be made considering that it merely reads paper
tape. The type of recovery procedures should be "Plot next feature", "Plot
next point" and "End Session". These actions can be effectively accomplished
using searching techniques on graphic data residing in mass storage.

APPENDIX A

A

CARTOGRAPHIC SYSTEM

DEMONSTRATION

SESSION

## PREFACE

The purpose of this Appendix is to give the potential user an insight as to how the Cartographic System works in an actual work session.

Each page of this manual is divided into two (2) parts. The top part is a reproduction of the actual display seen during a session, while the bottom of the page contains explanations of what the displays represent and typical digitizing session procedures.

```
TYPE 0 TO 6 CHARACTER JOB ID   CARTO

NEW JOB ACCEPTABLE? (Y OR N)  Y

NEW JOB -- DEFINE PARAMETERS

TYPE DISK RESOLUTION (1 TO 10)  4

TYPE MAGNETIC TAPE RESOLUTION (1 TO 99)  99
```

----------------------------------------------------------------------

In response to the user's action of typing CS (carriage return) the above questions are presented to the operator. The operator can either verify that a new job is desired or restart the process of typing 'N'.

Disk recording resolution and MMS output tape resolution are input by the user at this time. They may be changed later in HEADER MODE.

HEADER-SELECTION MODE -- SELECT MAJOR FEATURE CLASS:

CONTROLLO PUNTI

VIE DI COMUNICAZIONE FERRATE

VIABILITA, ELEMENTI DIVISORI, PASSAGI DI CORSI D'ACQUA

ABITATI, COSTRUZIONI, OPERE MURARIE VARIE

IMPIANTI PER TRASPORTI E TELECOMUNICAZIONI

IDROGRAFIA

VEGETAZIONE

LIMITI AMMINISTRATIVI

OROGRAFIA

ELEMENTI PLANIMETRICI, ALTIMETRICI, E BATOMETRICI

TUTTO

Since a new job is being started, the operator must pick his headers or definitions for the features to be digitized. The choice of either one of the above, or all eight major feature categories is given. The operator responds by placing the horizontal crosshair through a category and striking any key.

A-4

```
0201030   FERROVIA AD UN BINARIO A SCARTAMENTO ORDINARIO
0202030 * FERROVIA A DUE BINAPI A SCARTAMENTO ORDINARIO
0203030   FERROVIA A TRAZIONE ELETTRICA
0204030   ROTABILE FIANCHEGGIANTE LA FERROVIA
0205030   FERROVIA A SCARTAMENTO RIDOTTO,TRANVIA A VAPORE
0206030 * FERROVIA A SCARTAMENTO RIDOTTO, ELETTRICA
0207015 * TRANVIA IN SEDE STRADALE
0208015 * STRADA PERCORSA DA FILOVIA
0209030   CAVALCAVIA
0210030 * SOTTOPASSAGGIO
0211030   PASSAGGIO A LIVELLO
0212030 * PASSAGGIO A LIVELLO CON CHIUSURA PERMANENTE AL TRANSITO
0213030   FERROVIA IN COSTRUZIONE AD UN BINARIO
0214030 * FERROVIA IN COSTRUZIONE A DUE BINARI
0215030   FERROVIA IN DISARMO O IN ABANDONO, AD UN BINARIO
0216030 * FERROVIA IN DISARMO O IN ABANDONO, A DUE BINARI
          DISPLAY NEXT GROUP
          CLOSE SELECTIONS FILE
```

Candidate features from the header library file are displayed on 'pages' of 16 headers each. Each header consists of an identifying code and lineweight number, and a free text description. The features are picked for inclusion into the job's working header set by first placing the display screen horizontal cursor through a header and striking any key. This is evidenced by the appearance of an asterisk between the header number and header text.

The header selection process is completed by placing the screen cursor through 'CLOSE SELECTIONS FILE' and striking a key on the display console.

A-5

```
REFERENCE TABLE: PUSH GREEN BUTTON AT 0,0

-- GRAPHIC REGISTRATION --

PUSH WHITE PB AT REG. PT.1

PUSH WHITE PB AT REG. PT.2

PUSH WHITE PB AT REG. PT.3

PUSH WHITE PB AT REG. PT.4
```

---

Four registration points must be entered for each new job to define its position on the digitizer table. Before this can be done, the operator must first denote (0,0) on the table so that the registration points may represent actual values or distances from the table origin.

```
HEADER MODE -- RED = DECREMENT HDR MARKER    WHITE = ENTER POINT MODE
               YELLOW = INCREMENT HDR MARKER  GREEN = CHANGE HEADER ON
               BLUE = ENTER TRACE MODE                CURRENT/LAST FEATURE

0216030  FERROVIA IN DISARMO O IN ABANDONO, A DUE BINARI
0214030  FERROVIA IN COSTRUZIONE A DUE BINARI
0212030  PASSAGGIO A LIVELLO CON CHIUSURA PERMANENTE AL TRANSITO
0210030  SOTTOPASSAGGIO
0208015  STRADA PERCORSA DA FILOVIA
0207015  TRANVIA IN SEDE STRADALE
0206030  FERROVIA A SCARTAMENTO RIDOTTO, ELETTRICA
0202030  FERROVIA A DUE BINARI A SCARTAMENTO ORDINARIO
0308020  CARRARECCIA
0307010  ROTABILE SECONDARIA DA LARGHEZZA 2,5 - 3,5 M
0305020  FONDO PER STRADA CON RIVESTIMENTO LEGGERO
0305020  FONDO PER STRADA CON RIVESTIMENTO DURO
0304010  STRADA AD UNA CORSIA, FRA 3,5 E 7 M.
0303015  STRADA A DUE O PIU CORSIE, 7 M. ED OLTRE
0302020 □ AUTOSTRADA SENZA SPARTITRAFFICO (SEMPRE CON FONDO COLORATO)
0301020  AUTOSTRADA CON SPARTITRAFFICO (SEMPRE CON FONDO COLORATO)

CURRENT ELEVATION VALUE:
```

--------------------------------------------------------------------

HEADER MODE is the central mode of CS operation.  All modes, except for job initialization and closing return the user to HEADER MODE when they are finished.

This is the HEADER MODE main display which consists of the job's working header set in pages of up to 16 headers, current elevation value, and instructions for use.

A blinking display cursor points to one of the headers in the list.  When the digitizing modes TRACE or POINT are accessed, the header referenced by this cursor becomes the header of the new feature to be digitized.

CONTROL CODES:

1 - CHANGE MODE OF RED(-) AND YELLOW(+) BUTTONS
2 - ENTER TEMPORARY ELEVATION VALUE
3 - APPEND NEW HEADER TO LAST PAGE
4 - ALTER CONTOUR-SERIES BASE VALUE
5 - INSERT TEMPORARY HEADER

6 - CHANGE DISPLAY SCALE
    (CURRENT IS:1)
7 - CHANGE OUTPUT MAGNETIC TAPE RECORDING RESOLUTION
    (CURRENT IS: 99)
8 - CHANGE DISK RECORDING RESOLUTION
    (CURRENT IS: 4)

[TYPE "RETURN" FOR NO CHANGE]

----------------------------------------------------------------

It is also possible to make certain parameter changes, and add new headers to the job working header set while in HEADER mode. This is accomplished by striking the ' ∧ ' key when the main HEADER MODE display is on the screen.

The above options are available for change.

TRACE MODE -- BLUE - END FEATURE AND RETURN TO HEADER MODE
GREEN - EDIT MODE    WHITE - TRACE/POINT SUBMODE
RED - SEGMENT EDIT MODE    (CURRENT SCALE IS   1)
TRACE/POINT SUBMODE -- WHITE-RECORD POINT
GREEN-RECORD PT & RETURN TO CONT. TRACE
BLUE-RECORD PT & RETURN HEADER MODE
030202Q   AUTOSTRADA SENZA SPARTITRAFFICO (SEMPRE CON FONDO COLORATO

CONT
TRPT
CONT
TRPT
CONT
TRPT
CONT
TRPT

---
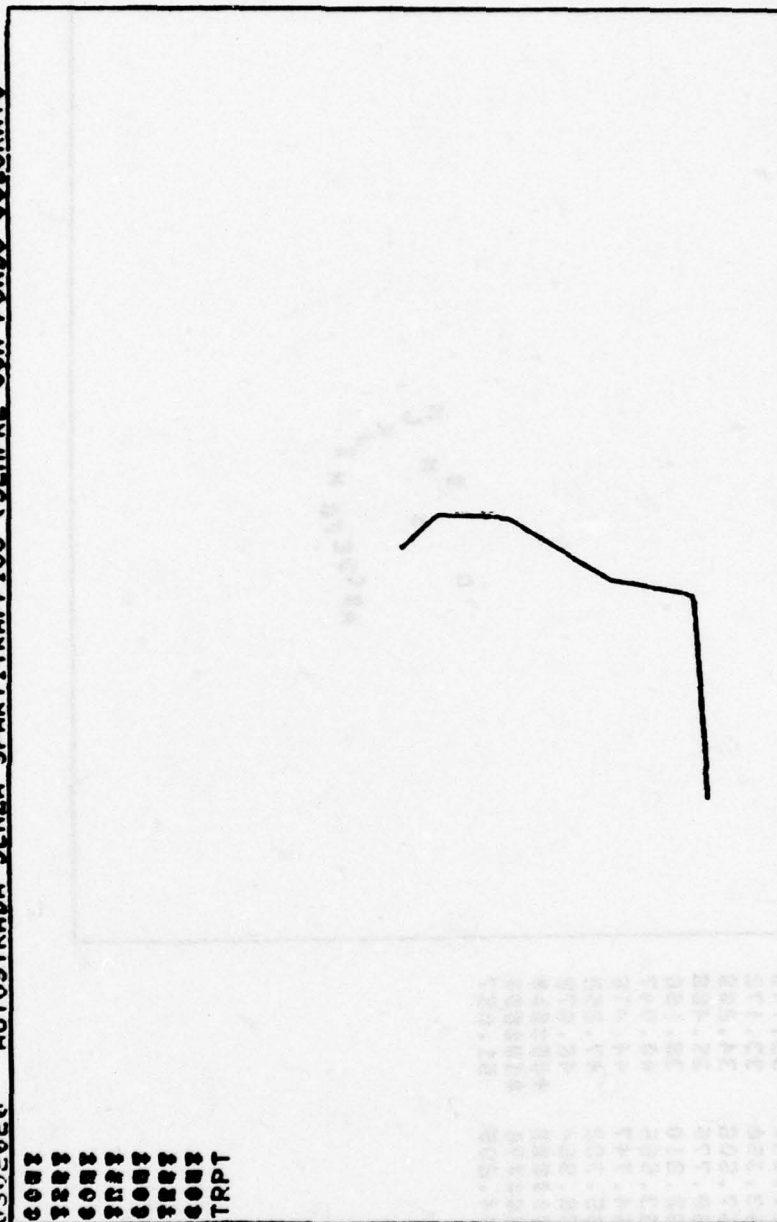
TRACE MODE is one of the two modes used for digitizing.  As seen above,
TRACE consists of a continuous submode and a Trace-Point submode.  In continuous
mode, any movement made by the cursor is recorded on disk.  There is no need to
continually press cursor buttons.  In Trace-Point mode, each time the White button
is pushed, a straight line vector is drawn from the previous cursor position (when
the White button was pushed) to the present cursor position.  Only the end points
of the line segment are stored.

The current submode of TRACE that the operator is using is shown by the 4-
character notation at the upper left corner of the square.

A-9

POINT MODE -- WHITE- RECORD A POINT   BLUE - RETURN TO HEADER MODE
                GREEN - DELETE LAST POINT RECORDED

0231020    STAZIONE PICCOLA

| | | |
|---|---|---|
| A | 39.855 | 35.855 |
| B | 41.979 | 36.297 |
| C | 44.587 | 36.886 |
| D | 46.421 | 35.672 |
| E | 48.852 | 35.060 |
| F | 51.534 | 35.749 |
| G | 53.350 | 33.172 |
| H | 57.506 | 34.209 |
| I | 60.775 | 35.466 |
| J | 62.210 | 38.166 |
| K | 63.556 | 40.947 |
| L | 64.747 | 44.478 |
| M | 65.382 | 47.252 |
| N | 58.964 | 46.678 |
| O | | |
| O | | |
| O | 44.295 | 51.057 |

POINT MODE is used to record discrete point features.  The square to the right
represents the entire digitizer surface at reduced scale.  Below the instructions
for POINT MODE use is the chosen feature header.  The list of numbers at the left
of the square represent the coordinate positions of the recorded point in units of
centimeters.  As each point is recorded, it is assigned a label starting with
the letter 'A'.  Inside the square are the noted positions of the points and their
position relative to the digitizing table.  Points which have their positions
and labels crossed out have been deleted.

A-10

TRACE MODE -- BLUE • END FEATURE AND RETURN TO HEADER MODE
GREEN • EDIT MODE    WHITE • TRACE/POINT SUBMODE
RED • SEGMENT EDIT MODE    (CURRENT SCALE IS   1 )

TRACE/POINT SUBMODE -- WHITE-RECORD POINT
GREEN-RECORD PT & RETURN TO CONT. TRACE
BLUE-RECORD PT & RETURN HEADER MODE

0317010  STRADA IN COSTRUZIONE, AD UNA CORSIA (FRA 3,5 E 7 M)
CONT

----------------------------------------------------------------------

In this case a feature has been digitized using continuous Trace submode (stream digitization). The hanging near-vertical segment represents an operator error and will be corrected in EDIT MODE.

EDIT MODE is entered from Continuous Trace by pushing the Green cursor button.

A-11

EDIT MODE -- WHITE = FIND A POINT    BLUE = EXIT TO TRACE MODE
RED = KEEP FEATURE AS DISPLAYED AND EXIT TO HEADER MODE
YELLOW = KEEP FEATURE AS ORIGINAL AND EXIT TO HEADER MODE
GREEN = DELETE FEATURE AND EXAMINE PREVIOUS
(CURRENT SCALE IS 1)

317 10  STRADA IN COSTRUZIONE, AD UNA CORSIA (FRA 3,5 E 7 M)

PASS 1 -- NOT AT "EDIT POINT"

----------------------------------------------------------------

A display of the last digitized feature first appears.  The message PASS 1 --
NOT AN EDIT POINT - indicates that no feature point nearest the cursor has been
calculated.

The operator now places his cursor on a correctly digitized part of the
feature near his mistake and pushes the White button.

A-12

EDIT MODE -- WHITE - FIND A POINT     BLUE - EXIT TO TRACE MODE
RED - KEEP FEATURE AS DISPLAYED AND EXIT TO HEADER MODE
YELLOW - KEEP FEATURE AS ORIGINAL AND EXIT TO HEADER MODE
GREEN - DELETE FEATURE AND EXAMINE PREVIOUS
(CURRENT SCALE IS 1)

317 10  STRADA IN COSTRUZIONE, AD UNA CORSIA (FRA 3,5 E 7 M)

CURSOR POSITION: X= 53.363  Y= 30.782
NEAREST PT FOUND: X= 53.350  Y= 30.785

The feature, up to the location of the cursor position where White was pushed, is displayed.  The rest of the feature may then be updated by TRACE, by pushing the Blue button at the EDIT Point.

A-13

TRACE MODE -- BLUE - END FEATURE AND RETURN TO HEADER MODE
            GREEN - EDIT MODE      WHITE - TRACE/POINT SUBMODE
            RED - SEGMENT EDIT MODE      (CURRENT SCALE IS  1)

TRACE/POINT SUBMODE -- WHITE-RECORD POINT
              GREEN-RECORD PT & RETURN TO CONT. TRACE
              BLUE-RECORD PT & RETURN HEADER MODE

0317010   STRADA IN COSTRUZIONE, AD UNA CORSIA (FRA 3,5, E 7 M)

CONT
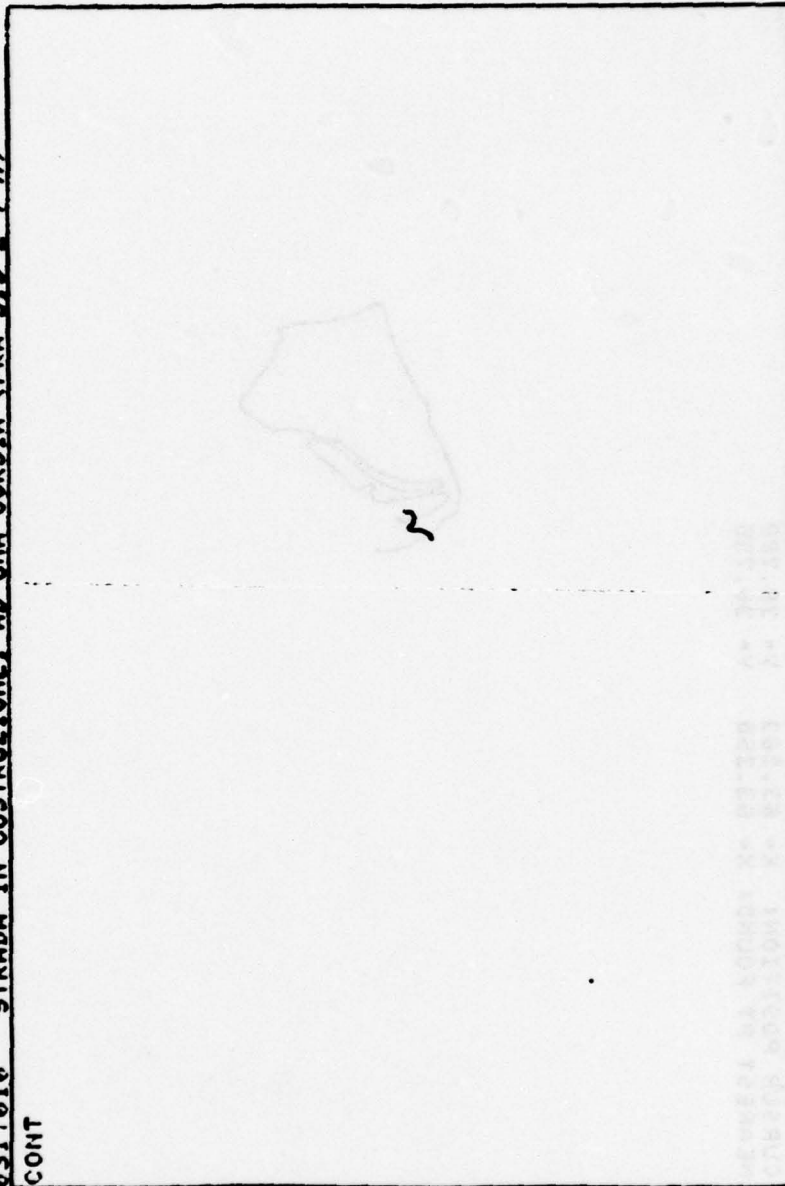
The update of the feature is now traced.

A-14

EDIT MODE -- WHITE - FIND A POINT     BLUE - EXIT TO TRACE MODE
RED - KEEP FEATURE AS DISPLAYED AND EXIT TO HEADER MODE
YELLOW - KEEP FEATURE AS ORIGINAL AND EXIT TO HEADER MODE
GREEN - DELETE FEATURE AND EXAMINE PREVIOUS
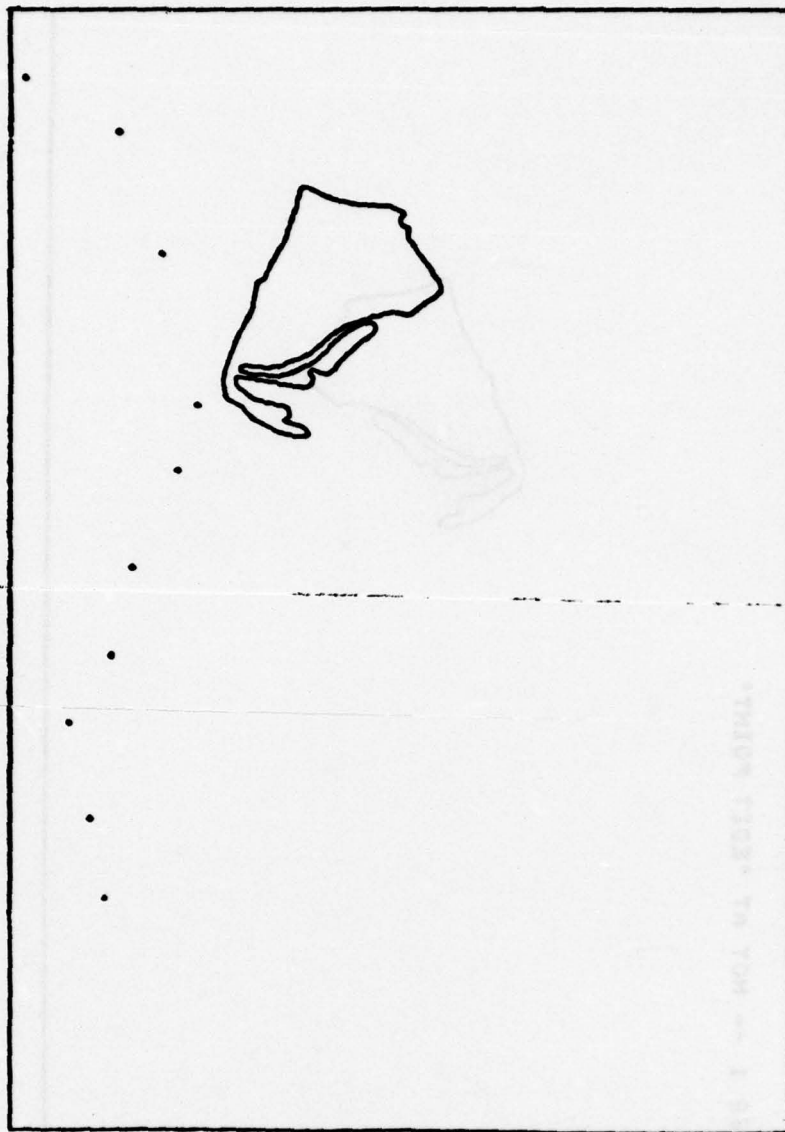(CURRENT SCALE IS 1)

317 10 STRADA IN COSTRUZIONE, AD UNA CORSIA (FRA 3,5 E 7 M)

PASS 1 -- NOT AT 'EDIT POINT'

The operator returns to EDIT mode to see the results of his update. The corrected feature may now be stored on disk.

REVIEW MODE -- WHITE = PLOT NEW WINDOW
RED = STOP PLOT
BLUE = RETURN TO HEADER MODE
YELLOW = CHANGE DISPLAY SCALE OR "CLASS MASK"
(CURRENT SCALE IS 1   CLASS MASK IS T )

REVIEW MODE is used to examine all the digitized data within a window area centered around the digitizing cursor.  This window may be moved, reduced or expanded to show more data or to highlight specific features.

Both discrete point and string data may be displayed.

A-16

```
ENTER 1 TO CHANGE DISPLAY SCALE
      2 TO CHANGE CLASS MASK 2

CLASS CODES:
1 - CONTROLLO PUNTI
2 - VIE DI COMUNICAZIONE FERRATE
3A - VIABILITA PRINCIPALE E SECONDARIA
3B - CONDIZIONI PARTICOLARI DI STRADE
3C - INDICATORI STRADALI
3D - PARTICOLARI RELATIVI ALLE STRADE
3E - ELEMENTI DIVISORI
3F - PASSAGGI DI CORSI D'ACQUA
4A - ABITATI, COSTRUZIONI INDUSTRIALI E RELIGIOSE
4B - OPERE MURARIE VARIE
5 - IMPIANTI PER TRASPORTI E TELECOMUNICAZIONI
6 - IDROGRAFIA
7 - VEGETAZIONE
8 - LIMITI AMMINISTRATIVI
9 - OROGRAFIA
0 - ELEMENTI PLANIMETRICI, ALTIMETRICI E BATOMETRICI
T - TUTTO

                              T
```

--------------------------------------------------------------------

   It is possible to selectively examine all the data within a specific
feature category by choosing one of the above class codes.  'T' chosen above
will show all data regardless of category.

ENTER 1 TO CHANGE DISPLAY SCALE
2 TO CHANGE CLASS MASK 1

ENTER SCALE: 1 TO 9 --
(PRECEDE DIGIT BY '/' FOR REDUCED SCALE /2

---

As mentioned previously, the scale factor may be used to allow examination of all or highlighted features.  Changing the display scale does not modify any feature data recorded on disk.

REVIEW MODE -- WHITE = PLOT NEW WINDOW
RED = STOP PLOT
BLUE = RETURN TO HEADER MODE
YELLOW = CHANGE DISPLAY SCALE OR 'CLASS MASK'
(CURRENT SCALE IS 1/2   CLASS MASK IS T )

----------------------------------------------------------------

This display represents the combined action of expanding the window size (reducing scale) and shifting the window position.

REVIEW MODE -- WHITE = PLOT NEW WINDOW
RED = STOP PLOT
BLUE = RETURN TO HEADER MODE
YELLOW = CHANGE DISPLAY SCALE OR "CLASS MASK"
(CURRENT SCALE IS 4   CLASS MASK IS T )
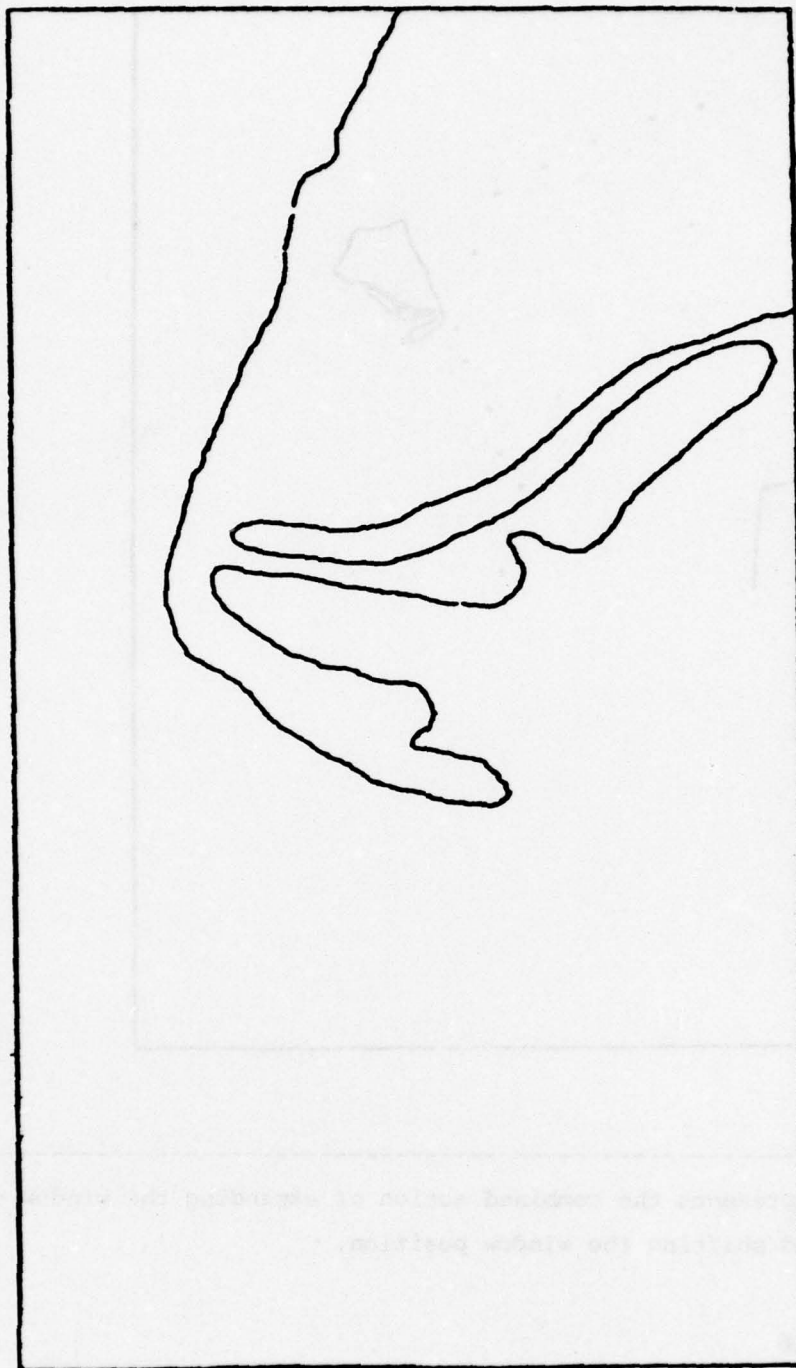
An example of feature highlighting through enlarged scale.

A-20

EDIT MODE -- WHITE • FIND A POINT    BLUE • EXIT TO TRACE MODE
RED • KEEP FEATURE AS DISPLAYED AND EXIT TO HEADER MODE
YELLOW • KEEP FEATURE AS ORIGINAL AND EXIT TO HEADER MODE
GREEN • DELETE FEATURE AND EXAMINE PREVIOUS
    (CURRENT SCALE IS 3)

317 10 STRADA IN COSTRUZIONE AD UNA CORSIA (FRA 3,5 E 7 M)

PASS 1 -- NOT AT "EDIT POINT"

---------------------------------------------------------------
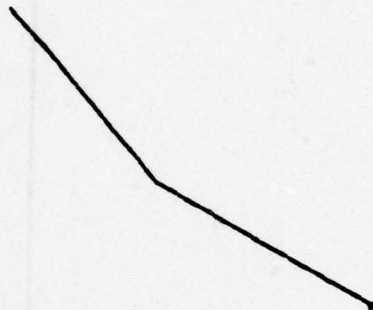
    A digitizing error had been made.  Using EDIT MODE to inspect the feature,
the operator determines that an angular segment within the feature is missiong.
To perform interior segment editing, the operator must use SEGMENT EDIT mode.
First he must draw a replacement string, in the above case, by entering HEADER
MODE, and then TRACE mode.  Then he must invoke SEGMENT EDIT to perform the
replacement.  This procedure is illustrated in the following pages.

A-21

TRACE MODE -- BLUE = END FEATURE AND RETURN TO HEADER MODE
GREEN = EDIT MODE    WHITE = TRACE/POINT SUBMODE
RED = SEGMENT EDIT MODE    (CURRENT SCALE IS   3 )

TRACE/POINT SUBMODE -- WHITE=RECORD POINT
GREEN=RECORD PT & RETURN TO CONT. TRACE
BLUE=RECORD PT & RETURN HEADER MODE

6J17010    STRADA IN COSTRUZIONE, AD UNA CORSIA (FRA 3.5 E 7 M)

6083
TRPT

The operator returns from EDIT mode to Header Mode with the erroneous

feature in tact. He then  enters TRACE mode to draw the replacement segment

needed.

A-22

SEGMENT EDIT MODE -- WHITE = FEATURE SEARCH    BLUE = ACCEPT FEATURE FOR EDIT
RED = CHANGE FEATURE HEADER    GREEN = DELETE FEATURE
YELLOW = CHANGE DISPLAY SCALE OR SEARCH TOLERANCE
        (CURRENT SCALE IS 3 -- TOLERANCE IS 32 MILS)
R = REVERSE SEGMENT DIRECTION    CARR RET = EXIT

---
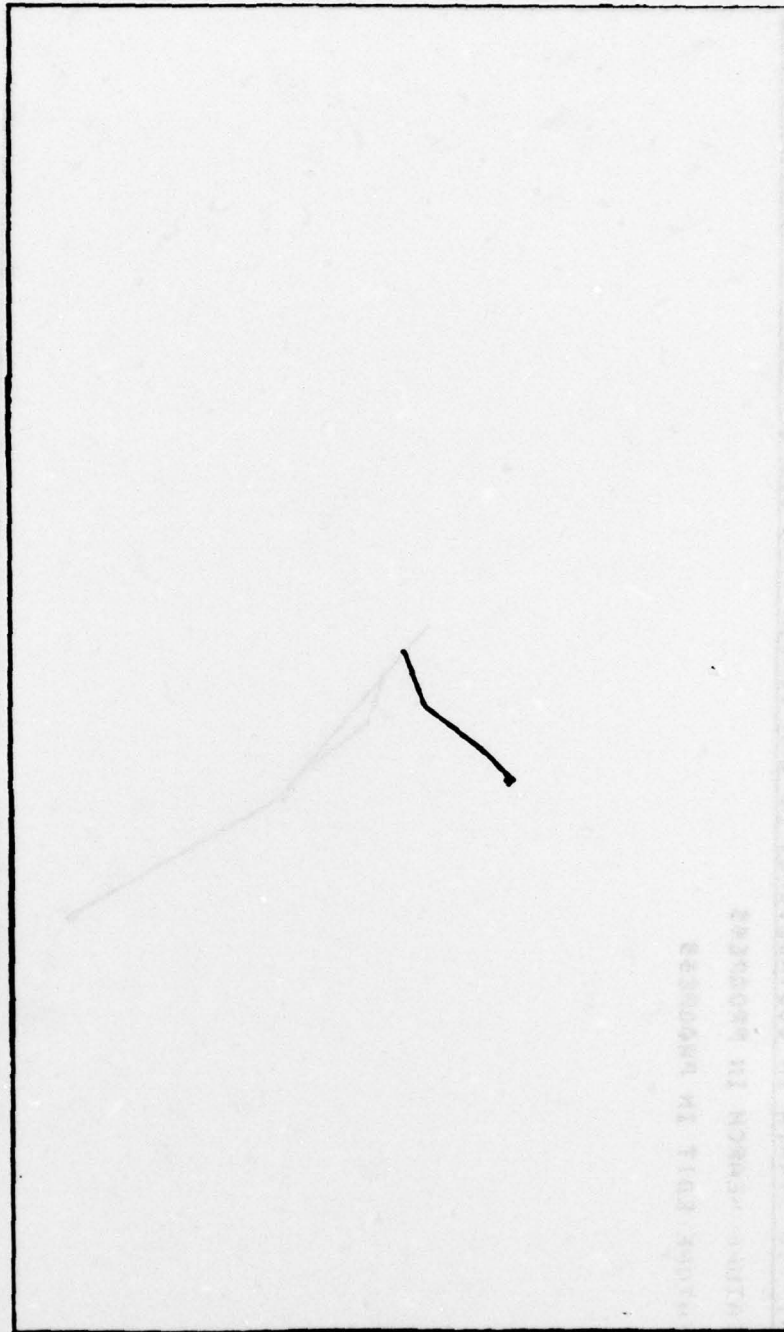
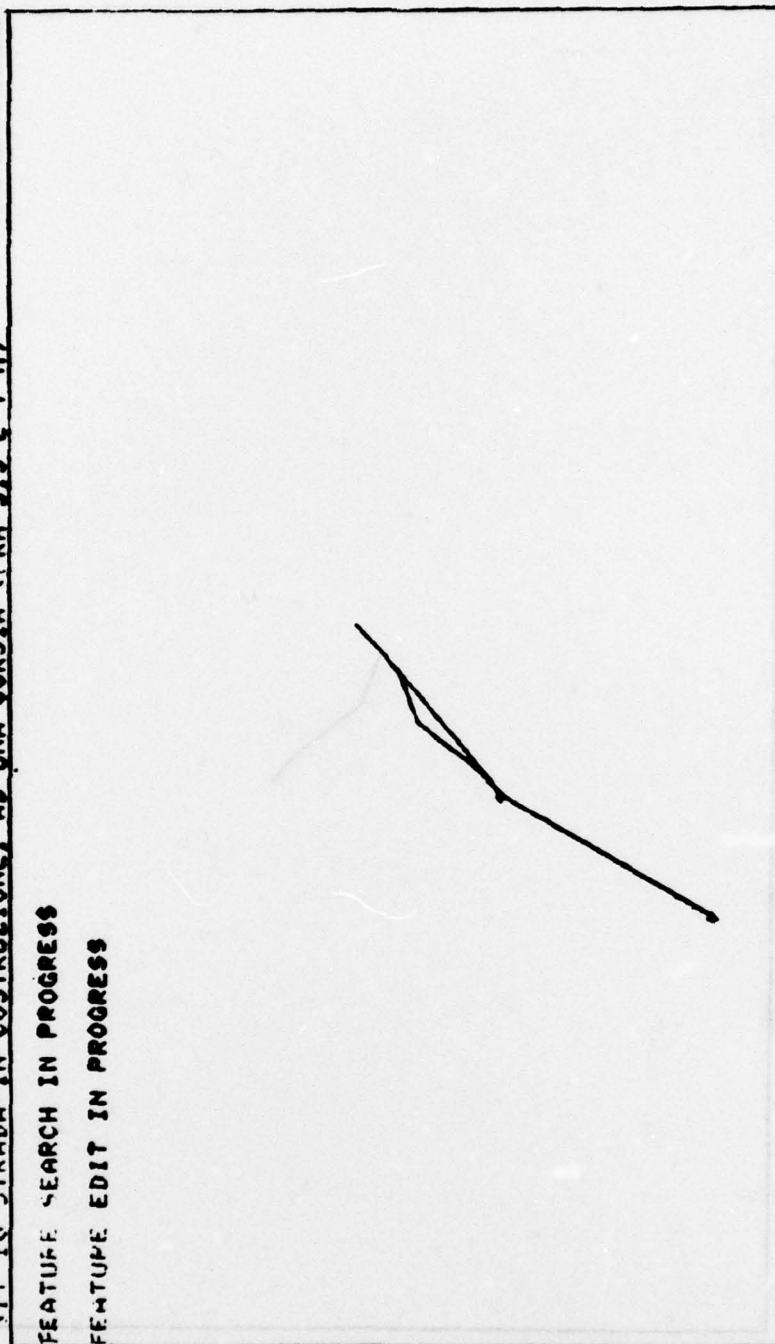The traced feature now becomes a segment after SEGMENT EDIT mode is
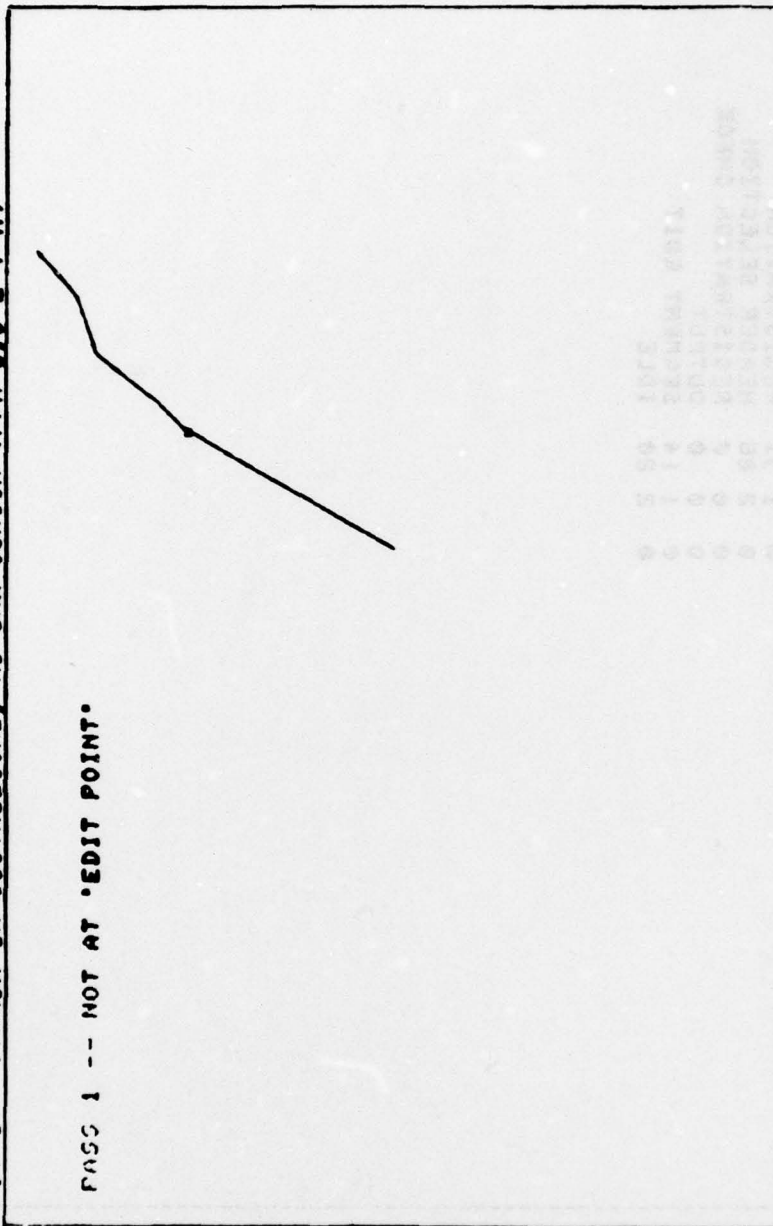entered.  The symbol at the end of the segment shows its direction.

A search is made for the feature closest to the segment end points.  Once found, the feature header appears at the top of the display square, and the feature is drawn relative to the segment position.

The operator can now update his feature with the correct segment.

EDIT MODE -- WHITE - FIND A POINT    BLUE - EXIT TO TRACE MODE
RED - KEEP FEATURE AS DISPLAYED AND EXIT TO HEADER MODE
YELLOW - KEEP FEATURE AS ORIGINAL AND EXIT TO HEADER MODE
GREEN - DELETE FEATURE AND EXAMINE PREVIOUS
(CURRENT SCALE IS 3)

FIG 10   STRADA IN COSTRUZIONE, AD UNA CORSIA (FRA 3,5 E 7 M)

PASS 1 -- NOT AT 'EDIT POINT'



The updated feature is now examined in EDIT mode for correction.

```
H   M   S
0   3  37   HEADER
0   3  30   TRACE
0   2  42   TRACE-POINT
0   7  19   EDIT
0   1  47   POINT
0   5  45   REVIEW
0   1  31   REGISTRATION
0   2  26   HEADER SELECTION
0   0   0   REGISTRATION CHECK
0   0   0   OUTPUT
0   1  14   SEGMENT EDIT
0   2  20   IDLE
```

--------------------------------------------------------------------------------

To close a job session the operator types 'C' while in HEADER MODE.  The
cumulative time spent in each mode in Hours, Minutes and Seconds appears on
the display.

A-26

REFERENCE TABLE: PUSH GREEN BUTTON AT 0.0

-- GRAPHIC REGISTRATION --

RE-REGISTER GRAPHIC? (Y OR N)   Y

PUSH WHITE PB AT REG. PT.1

PUSH WHITE PB AT REG. PT.2

PUSH WHITE PB AT REG. PT.3

PUSH WHITE PB AT REG. PT.4

---

The job CARTO has been reopened.  Assumming. that the graphic was remounted, new registration points were entered.

-- REGISTRATION CHECK --

| ORIGINAL REGISTRATION POINTS | NEW REGISTRATION POINTS | DYNAMIC CORRECTIONS | ADJUSTED REGISTRATION POINTS | ERROR |
|---|---|---|---|---|
| 11796.0 | 12759.0 | -963 | 11796.0 | 0.0 |
| 4338.0 | 4298.0 | 40 | 4338.0 | 0.0 |
| 12283.0 | 13722.0 | -1439 | 12283.0 | 0.0 |
| 27062.0 | 27027.0 | 35 | 27062.0 | 0.0 |
| 28864.0 | 29224.0 | -360 | 28864.0 | 0.0 |
| 26720.0 | 26711.0 | 9 | 26720.0 | 0.0 |
| 28405.0 | 28884.0 | -478 | 28406.0 | -1.0 |
| 3968.0 | 3882.0 | 85 | 3967.0 | 1.0 |

PUSH BLUE PB TO EXIT,OR
LIFT UP CURSOR TO RE-REGISTER

---

A check is performed to indicate whether new data entered will fit into the job's old frame of reference. To re-register the graphic, the cursor is lifted up.

A-28

TABLE POSITION LOST

REFERENCE TABLE: PUSH GREEN BUTTON AT 0,0

-- GRAPHIC REGISTRATION --

RE-REGISTER GRAPHIC? (Y OR N) Y

PUSH WHITE PB AT REG. PT.1

PUSH WHITE PB AT REG. PT.2

PUSH WHITE PB AT REG. PT.3

PUSH WHITE PB AT REG. PT.4

------------------------------------------------------------------------

Re-registration and origin select now takes place.

It is possible to obtain a proof plot of a CS job session by invoking the off-line Calcomp plotting processor software.

The following pages illustrate how plotting is accomplished.

CALCOMP PLOT MODE

TYPE 0 TO 6 CHARACTER JOB ID  CARTO

The job name of the digitized file is entered.

---

Pens are assigned to feature categories in the same way that Headers are selected in the CS, that is, through use of the horizontal cursor.

The operator may assign pens 1 to 3 of the plotter to any feature category, and may also omit categories to perform selective plotting. Notice the crossout of the category VIABILITA, etc. This is performed by typing Ø when the cursor passes through the desired feature category.

A-32

```
LIST STARTING X,Y COORDS ?
0-NONE 1-ON $TTO 2-ON $TTO1  ●

TYPE OUTPUT SCALE (0.1 TO 10.0)  1

TYPE 1 FOR QUICK PLOT, 0 FOR NORMAL  ●

POSITION TURRET TO EXTREME RIGHT
TYPE CARR. RET. WHEN READY

END OF PLOT

TYPE 0 TO STOP
     1 TO PLOT OVERLAY
```

---------------------------------------------------------------------------------

The above messages are displayed as Calcomp processing continues.  The operator may have more than the 3 pen colors available at one time in the pen turret by changing pens and plotting an overlay.

CS job files may be converted into a format for the Contraves Coragraph Plotter. The next illustration depicts a typical CS to Contraves conversion job session.

```
CS TC CONTRAVES TASK
TURN PAPER TAPE PUNCH ON

TYPE 0 TO 6 CHARACTER JOB ID  CARTO

SELECT OFFSETS(-8 TO 8 METERS):

X OFFSET(M)= 0

Y OFFSET(M)= 0

PT SELECT (0-1000)= 100

OUTPUT LIST FILE (0-NO 1-YES)? 1

CS TO CONTRAVES TASK COMPLETED
CONTRAVES TAPE IS BEING PUNCHED

OUTPUT LIST FILE IS BEING GENERATED.

OUTPUT LIST FILE ELFCARTO 3 COMPLETED.
```

--------------------------------------------------------------------------------

The CS-created job name is entered.  Any offset and culling adjustment of cartographic data is then input, and the option of any easy-to-read list file of the converted data is presented.

As each of the various CONTRAVES processing phases are completed, messages are output to inform the user.